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Subject: Procedures to Estimate Characteristics and Population of Dilute and Concentrated Streams for Model Processes--Pesticide Active Ingredient Production NESHAP  
EPA Contract No. 68D60012; Task Order No. 0004  
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## I. Introduction

The model plants memorandum describes parameters for four model processes that are used to characterize process vent emissions at modelled plants; each model process characterizes both a dilute stream and a concentrated stream.<sup>1</sup> The objectives of this memorandum are to: (1) describe the methodology used to estimate the flow rates (and corresponding organic HAP concentrations) for these eight streams and (2) estimate the number of processes at the 58 modelled plants that are represented by dilute and concentrated streams. The methodology is described in Sections II and III, and the distribution of dilute and concentrated models is described in Section IV.

## II. Cutoffs for Model Streams

The first step in the methodology was to determine the flow rates and associated concentrations that define the cutoff, or cross-over point, between dilute and concentrated streams for each model process. This was accomplished by estimating the costs to control the organic HAP emissions from the model processes with an incinerator and a condenser over a range of flow rates. The cutoff is the flow rate for which the control costs are equal. Dilute streams are streams with flow rates above the cutoff, and for which control with an incinerator is the least costly alternative. Flow rates below the cutoff characterize concentrated streams, and the least costly control alternative for these streams is to use a condenser. Graphs of the costs for each model, and examples of the algorithms used to calculate the costs, are shown in attachment 1.

The algorithms used to estimate the costs are the same as those used to estimate cost impacts for regulatory alternatives.<sup>2</sup> In the algorithms, the annual HAP emissions and operating hours are fixed based on the model characteristics. Thus, as flow rate increases, the HAP concentration decreases. The average organic HAP concentration at the flow rate cutoff was calculated using the annual mass emissions for the model process, the ideal gas law at standard conditions, and the process operating hours (i.e., 2,800 h/yr for batch model processes and 5,000 h/yr for continuous model processes).<sup>1</sup> Model processes 2 and 4 are designed with both toluene and methylene chloride emissions, but, for simplicity, this analysis assumes that the entire organic HAP emissions from these models are methylene chloride. An example calculation is presented in attachment 2, and the results are presented in Table 1.

TABLE 1. FLOW RATE CUTOFFS FOR MODEL PROCESSES

Model process	Annual emissions, lb/yr	Flow rate cutoff, scfm	Organic HAP concentration at flow rate cutoff, ppmv
1	30,200	1,390	540
2	88,200	285	8,340
3	90,400	760	1,660
4	224,400	230	14,730

## II. Model Flow Rates and Organic HAP Concentrations

The second step in the methodology was to determine the flow rates and concentrations above and below the cutoffs that represent the dilute and concentrated model streams, respectively. This was accomplished by using averages from the data for processes at the surveyed plants.

### A. Data From Surveyed Plants

The surveyed plants reported flows for 23 batch processes and 15 continuous processes. For each vent in these 38 streams, the reported organic HAP emissions, duration of venting episodes, and the flow rate are shown in attachment 3. When a reported venting duration was greater than the process operating hours, it was changed to be equal to the process operating hours; the changed values are shaded in attachment 3. For most processes, the maximum venting duration for a vent within the process is equal to the process operating hours. In a few cases, however, the maximum venting duration is less than the process operating hours; for these processes this analysis assumes that venting episodes from all vents overlap so that operating time for a control device would be equal to the venting duration for the vent with the longest duration.

Average flow rates were calculated for an aggregated (manifolded) stream from each of the 38 processes. The average flow rate is equal to the sum of the reported flow rates for each vent in the process if the duration of venting episodes is the same for all vents in the process. If the duration of venting episodes varied for the vents in a process, a weighted average flow rate was calculated for the process. Weighted flow rates for each vent were calculated by multiplying the reported flow rate for the vent by the reported duration of venting episodes for the vent and dividing by the maximum duration for any vent in the process. The weighted flow rates were then summed to give the average flow rate for the process. A sample calculation is presented in attachment 2.

Average concentrations were calculated for each of the 38 processes as follows. Average mass emission rates were calculated by dividing the annual mass emissions by the number of minutes for the largest venting duration for each process. These values were then converted to concentrations using the calculated average flow rates and the ideal gas law at standard conditions. An example calculation is presented in attachment 2. The resulting concentrations for each of the 38 processes are presented in Table 2, along with other reported and calculated characteristics.

#### B. Model Characteristics

The flow rates and concentrations for the model streams were estimated by averaging various groups of data in Table 2. For example, the averages for model 1 were calculated as follows. From Table 1, the concentration cutoff is 540 ppmv. In Table 2, six batch processes have aggregated emission streams with concentrations below this cutoff (i.e., dilute). The average flow rate and concentration for these streams are 2,950 scfm and 277 ppmv, respectively. Because the six surveyed processes have a wide range of annual mass emissions, not all of them have flows above the model 1 cutoff of 1,390 scfm, but the average is above the cutoff. Similarly, 17 batch processes in Table 2 are above the 540 ppmv cutoff (i.e., concentrated). The average flow rate and concentration for these streams are 683 scfm and 219,000 ppmv, respectively. The same approach was used to estimate the characteristics for models 2, 3, and 4. The results are shown in Table 3.

#### IV. Population of Dilute and Concentrated Streams

As stated in the model plants memorandum, model processes 1, 2, 3, and 4 represent 48, 19, 14, and 12 processes at modelled plants, respectively. The number of dilute and concentrated streams was estimated assuming the ratio of dilute to concentrated streams at the surveyed plants is representative of the industry as a whole. Thus, of the 48 processes represented by model 1, 13 are estimated to have dilute streams ( $48 \times 6/23 = 13$ ), and 35 have concentrated streams ( $48 \times 17/23 = 35$ ). Similar procedures were used to estimate the number of dilute and concentrated streams for models 2, 3, and 4; and the results are shown in Table 4.

TABLE 2. CHARACTERISTICS OF MANIFOLDED PROCESS VENT STREAM FOR  
PROCESSES AT SURVEYED PLANTS

Plant number	Process number	Type of HAP <sup>a</sup>	Venting time, h/yr	Emissions, Mg/yr	Max. flow rate, scfm	Avg. conc. at max. flow, ppmv	Avg. flow rate, scfm	Avg. conc. at avg. flow, ppmv
Batch processes								
23	90	C	1,340	0.206	1,400	50	1,400	50
23	89	C	2,320	0.355	1,400	50	1,400	50
3	7	C	8,160	0.693	80	240	80	240
23	94	C	4,370	65	6,884	375	6,884	375
21	70	U	127	0.447	1,083	954	1,050	455
23	93	C	4,150	58.7	6,884	489	6,884	489
21	71	U	148	0.82	1,080	1,030	1,067	821
21	72	U	169	0.857	1,080	1,010	1,063	861
21	73	U	189	0.969	1,080	1,010	1,063	973
21	68	U	4,056	28.5	1,080	1,070	1,078	1,001
21	67	C	8,400	129	3,818	1,200	3,818	1,200
21	69	U	570	5.81	1,080	1,450	1,080	1,450
23	92	C	360	1.88	270	3,190	270	3,190
12	38	C	1,170	24.3	2,650	4,300	1,993	5,270
12	37	C	1,368	4.59	76	10,300	76	10,300
17	60	C	1,548	0.337	0.962	37,667	0.962	37,667
5	15	C	6,039	51.9	23.7	111,000	23.7	111,000
6	16	U	4,404	16.5	9.5	236,000	9.5	236,000
12	40	C	1,568	48.2	48	615,000	6.3	264,000
20	66	U	840	81.8	50.8	515,000	50.8	515,000
7	17	U	6,072	33	20	569,000	20	569,000
3	11	C	8,160	0.403	0.025	977,000	0.025	977,000
3	12	U	4,176	0.782	0.145	992,000	0.145	992,000

Plant number	Process number	Type of HAP <sup>a</sup>	Venting time, h/yr	Emissions, Mg/yr	Max. flow rate, scfm	Avg. conc. at max. flow, ppmv	Avg. flow rate, scfm	Avg. conc. at avg. flow, ppmv
Continuous processes								
23	91	C	7,488	4.02	4,900	16	4,900	16
1	4	C	720	9.32	74,500	26	74,500	26
7	18	C	5,300	12.8	29,250	16	15,250	29
1	2	C	336	5.64	74,500	35	74,500	35
1	1	C	5,040	136	74,500	56	74,500	56
1	3	C	720	19.5	74,500	56	74,500	56
5	14	U	7,464	0.916	125	153	125	153
8	19	C	7,896	202	10,800	606	10,800	606
10	27	C	7,680	65.6	141	2,606	141	2,606
3	6	C	8,136	50.9	350	2,986	179	2,984
17	63	U	8,064	200	666	51,300	486	22,600
12	39	C	7,000	199	246	33,500	122	32,500
17	62	U	2,424	15.3	129	12,500	36	37,300
17	61	U	1,920	8.19	6.7	101,000	6.7	101,000
9	25	C	3,384	18.2	2	237,000	1.8	254,000

<sup>a</sup>C means the emissions include chlorinated organic HAP; U means the emissions consist only of unchlorinated organic HAP.

**TABLE 3. FLOW RATES AND ORGANIC HAP CONCENTRATIONS FOR MODEL PROCESSES**

Model process		Number of surveyed processes used in average	Model characteristics	
Number	Type of stream		Average flow rate, scfm	Organic HAP concentration at average flow rate, ppmv
1	Dilute	6	2,950	277
1	Concentrated	17	683	219,000
2	Dilute	14	2,080	1,170
2	Concentrated	9	21	412,000
3	Dilute	8	41,130	122
3	Concentrated	7	139	65,100
4	Dilute	10	32,940	947
4	Concentrated	5	131	89,500

In addition to representing processes at modelled plants, the model processes are also used to represent processes at the surveyed plants in cost impacts analyses. The surveyed processes that are represented are those that would have to add control to meet the proposed standard. Based on the data in attachment 1 of the environmental impacts report, a total of 28 processes at the surveyed plants would have to increase control levels to meet the requirements of the MACT floor and the regulatory alternatives.<sup>3,4</sup> The 28 surveyed processes are identified in Table 5. Eighteen of these processes are batch processes, and 10 are continuous processes. Based on the rankings in Table 2 and the flow rate cutoffs for the models, the models that represent 21 of the 28 processes can be readily determined. For example, for model process 1 the concentration associated with the flow rate cutoff is 540 ppmv. Batch processes 7, 70, 89, and 90 at the surveyed plants have lower concentrations; thus, these four processes are represented with the dilute model.

The surveyed plants did not report flow data for 7 of the 28 processes. However, a model was assigned based on knowledge about the type of HAP and the process operating hours. Processes 28, 29, 30, and 31 were reported to be batch/continuous processes, and processes 54, 57, and 58 were reported to be batch processes. To be included in the analysis, the batch/continuous processes were assumed to be either batch or continuous processes in

TABLE 4. POPULATION OF DILUTE AND CONCENTRATED MODEL PROCESS VENT STREAMS

Model process		Nationwide population at modelled plants
Number	Type of stream	
1	Dilute	13
1	Concentrated	35
2	Dilute	12
2	Concentrated	7
3	Dilute	7
3	Concentrated	7
4	Dilute	8
4	Concentrated	4
Total	Dilute	93

TABLE 5. MODEL PROCESSES USED TO REPRESENT SURVEYED PROCESSES

Model process		Surveyed processes represented by model process		Total number of processes
Number	Type of stream	Based on Table 2	Assigned	
1	Dilute	7, 70, 89, 90	54, 57	6
1	Concentrated	68, 69, 71, 72, 73	28, 30, 58	8
2	Dilute	67, 93, 94		3
2	Concentrated	15		1
3	Dilute	1, 2, 3, 4, 18	29	6
3	Concentrated	62		1
4	Dilute	27, 91	31	3
4	Concentrated			0
Total				28

approximately the same ratio as the known batch and continuous processes. Processes 28, 29, and 30 have only unchlorinated HAP emissions, and process 29 operates for more hours per year than the other two processes. Because batch processes are more prevalent than continuous processes in the PAI industry, two of these three processes were assumed to be represented with batch model 1 (processes 28 and 30), and one was assumed to be represented with continuous model 3 (process 29). Process 31 has both chlorinated and unchlorinated organic HAP emissions and operates for nearly 7,800 hours per year; thus, this process was assumed to be represented with continuous model 4. Processes 54, 57, and 58 have only unchlorinated emissions; thus, they were all assumed to be represented with batch model 1. The next step was to determine if these seven processes should have a dilute or concentrated stream. Processes 29 and 31 were assumed to have dilute streams because Table 2 shows dilute streams are more prevalent than concentrated streams for models 3 and 4. Table 2 also shows concentrated streams are more prevalent than dilute streams for model 1. Thus, three of the five surveyed processes represented by model 1 were assumed to be concentrated; processes 28, 30, and 58 were randomly selected.

#### V. References

1. Memorandum from D. Randall and K. Schmidtke, MRI, to L. Banker, EPA:ESD. April 30, 1997. Model Plants for the Pesticide Active Ingredient Production Industry.
2. Memorandum from K. Schmidtke and D. Randall, MRI, to L. Banker, EPA:ESD. April 30, 1997. Cost Impacts for the Pesticide Active Ingredient Production NESHAP.
3. Memorandum from D. Randall and K. Schmidtke, MRI, to L. Banker, EPA:ESD. April 30, 1997. Environmental Impacts for the Pesticide Active Ingredient Production NESHAP.
4. Memorandum from D. Randall and K. Schmidtke, MRI, to L. Banker, EPA:ESD. April 30, 1997. MACT Floor and Regulatory Alternatives for the Pesticide Active Ingredient Production Industry.

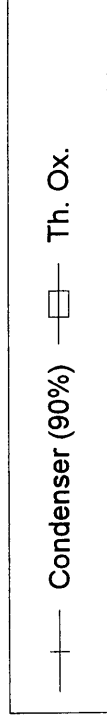
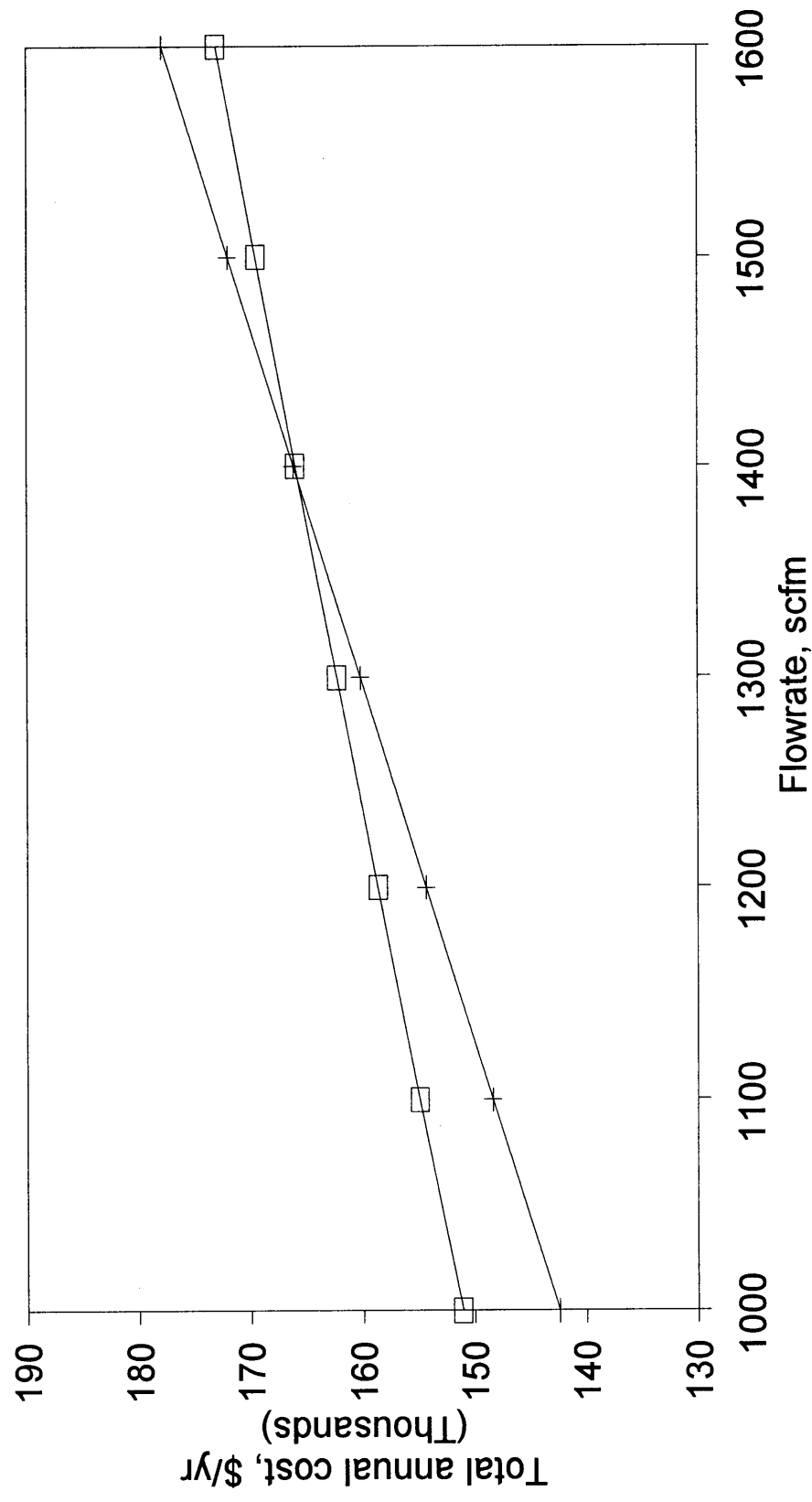
## Attachment 1

1. Graphs of annual cost versus flow rate for each of the four model processes
2. Example incinerator algorithm for model process 1
3. Example condenser algorithm for model process 1



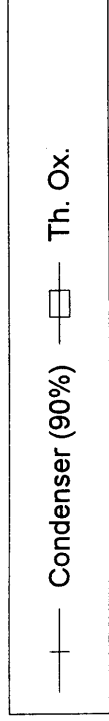
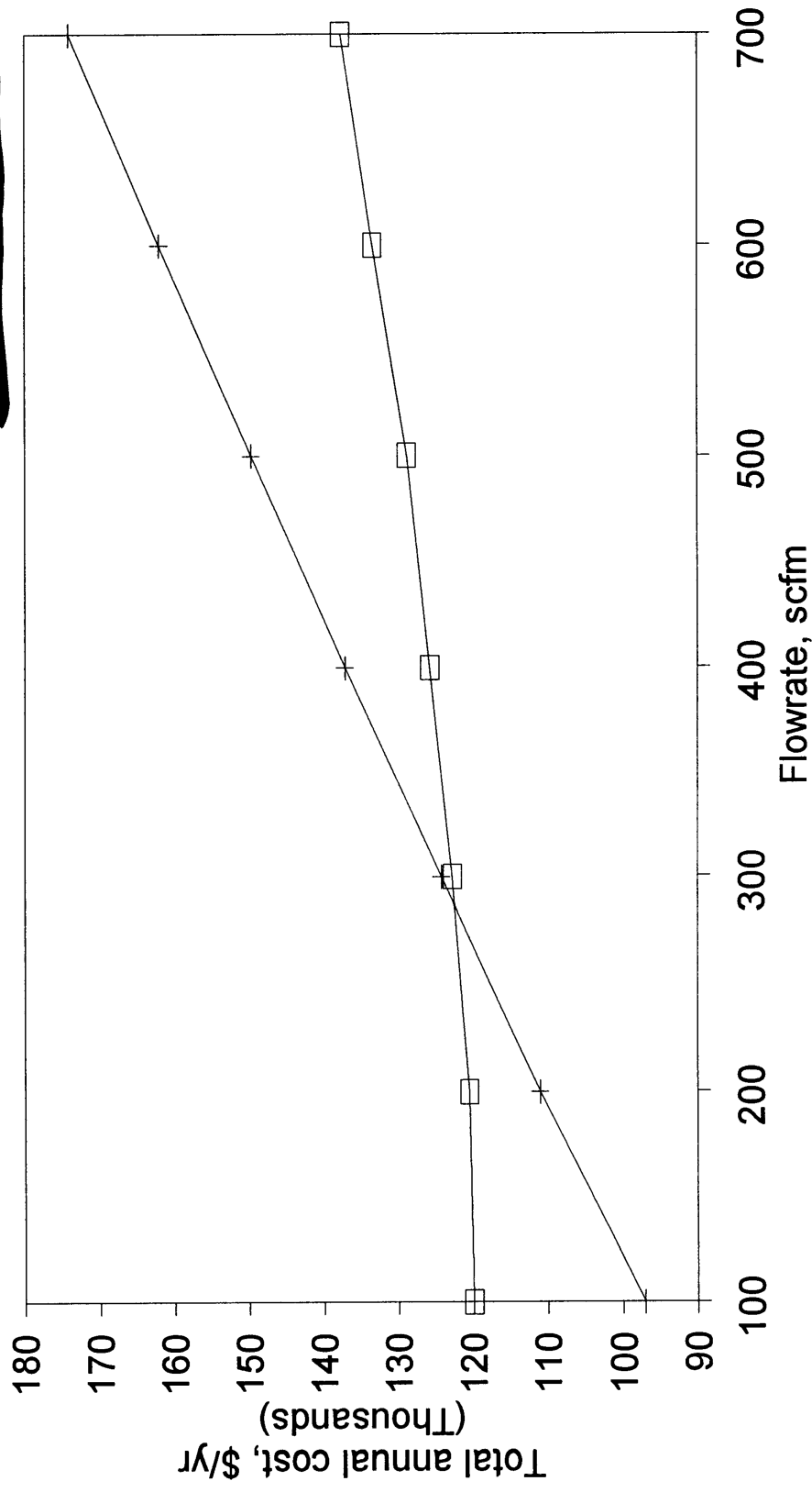
# MODEL 1 COSTS

Toluene (30,200 lb/yr)



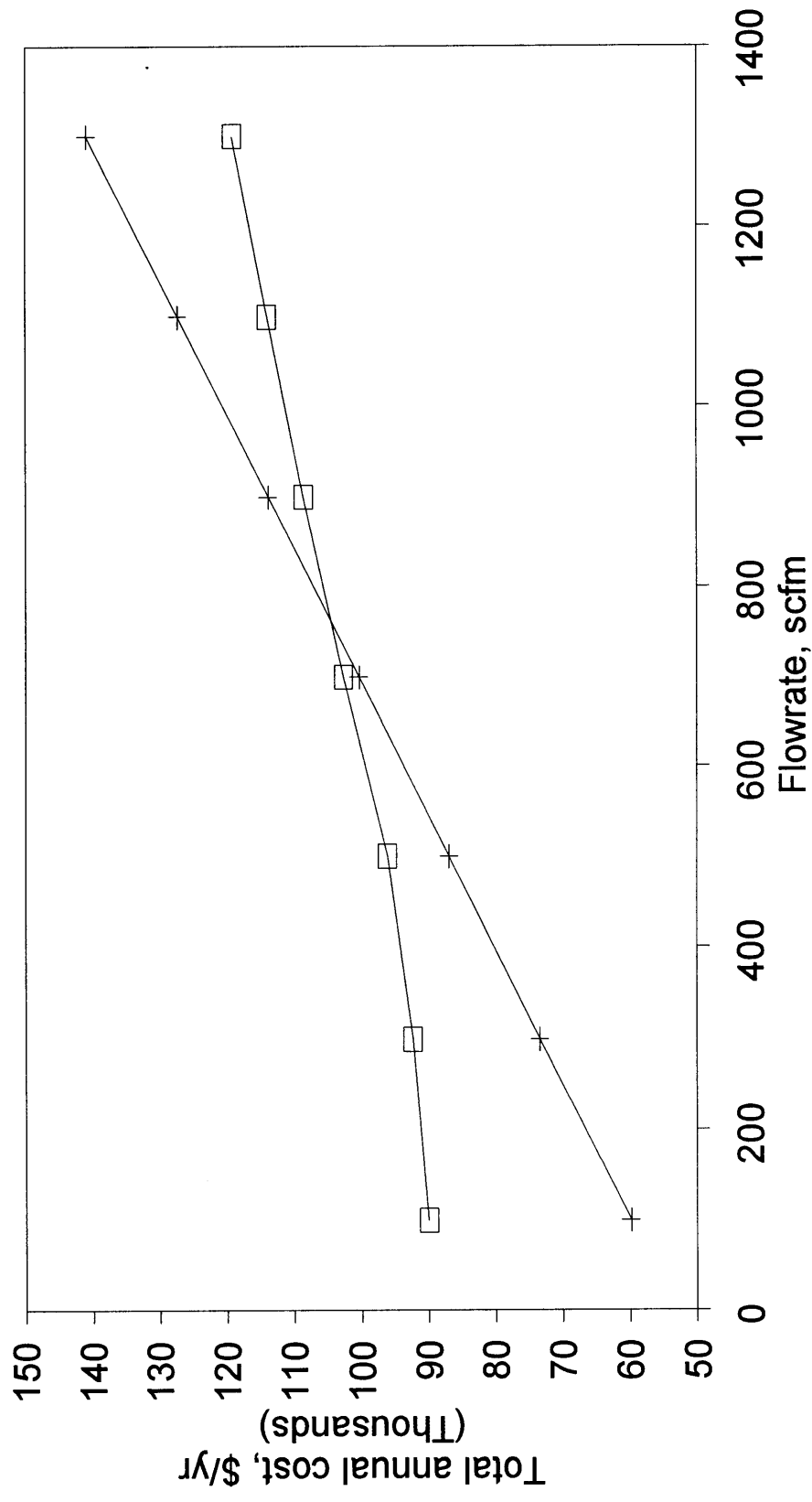
# MODEL 2 COSTS

Methylene Chloride (88,200 lb/yr)



# MODEL 3 COSTS

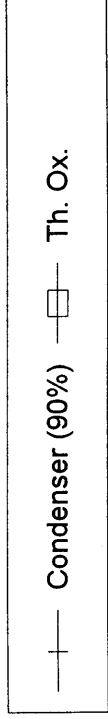
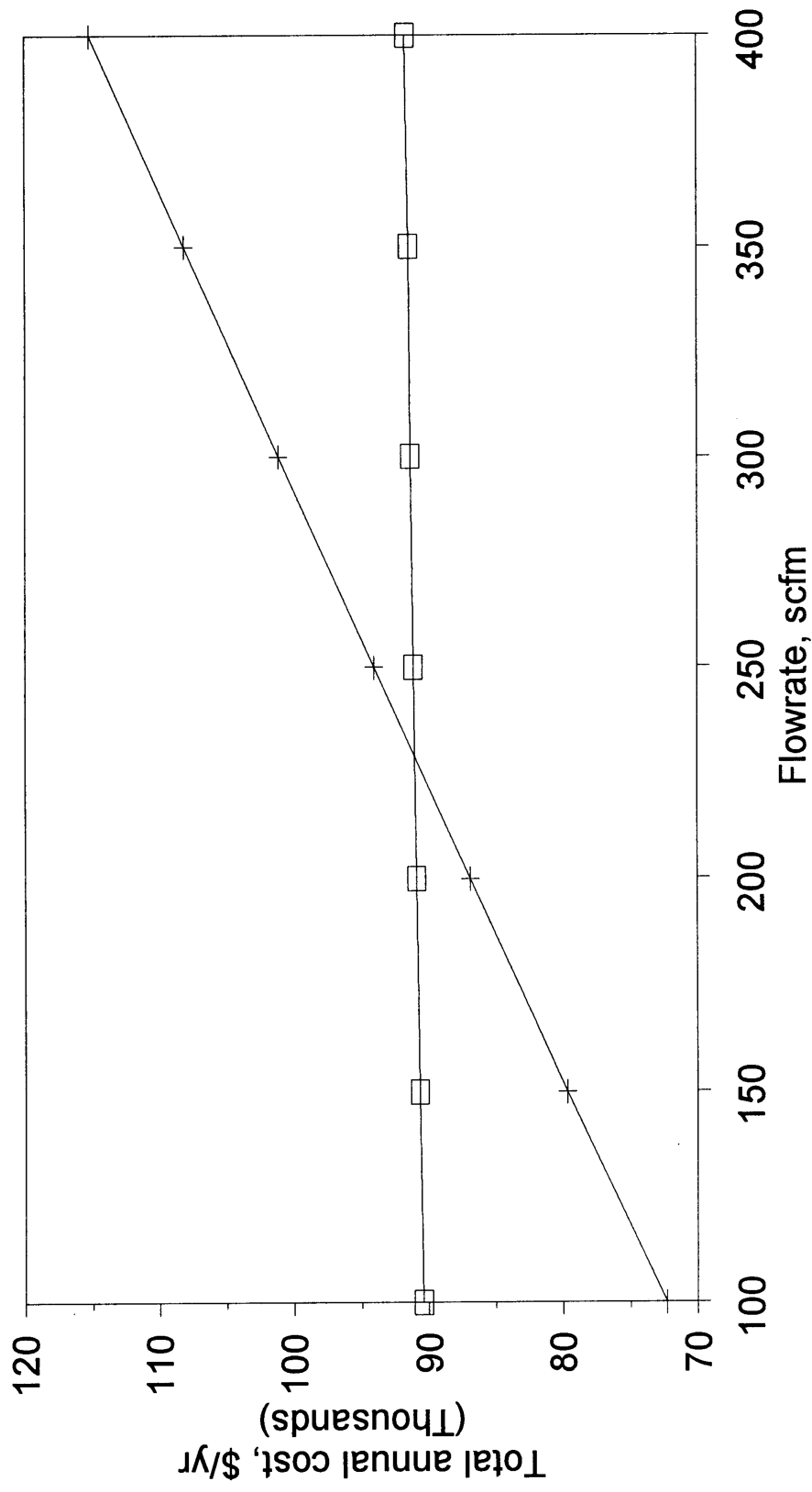
Toluene (90,400 lb/yr)



—+— Condenser (90%) —□— Th. Ox.

# MODEL 4 COSTS

Methylene Chloride (224,400 lb/yr)



## THERMAL INCINERATOR COST ALGORITHM

Process vents model:	1	
Waste gas parameters		HAP'S CONTROLLED (98% of input), Mg/yr
1. Mass flux of HAP, lb/yr	30,200	13.44
1. Volumetric flow rate, scfm	1,000.0	
2. HAP concentration, ppmv	752	COST EFFECTIVENESS (\$/Mg)
3. Assumed heating value of HAPs, Btu/scf HAP	2,000	11,244
4. Temperature, deg. F	77	
5. Molecular weight of HAP	92 Toluene	
6. Molecular weight of gas	29.05	
Operating hours, hr/yr		
Vents	2,800	Vh
Control device	8,760	CDh
Ratio of HAP venting time to control device operating time	0.3196	Ratio=Vh/CDh
Equipment design parameters		Variables/Equations
Manifolding		
Number of vents	6	Vents
Diameter of collection main, ft	0.80	
- calculated assuming velocity of 2,000 ft/min		
Length of duct, ft	300	L
Number of elbows in duct per vent	2	N
Number of dampers	1	
Incinerator		
Energy recovery, percent	70	
Operating temperature, deg. F	1600	
Calculate natural gas requirements		
STEP 1: Calculate total waste gas flow into incinerator		
Calculate O2 content, vol percent	20.98	
Calculate dilution air for combustion, scfm	0.00	
Calculate dilution air for safety, scfm	0.00	
Total gas flow into incinerator, scfm	1000.00	scfmi
Step 2: Calculate heat content of waste gas into incinerator, Btu/scf	1.50	
Step 3: Calculate waste gas temperature out of preheater, deg. F	1,143	
- calculated assuming amount of auxiliary fuel and dilution air are small so that mass flow rates on both sides of the preheater are about the same.		
Step 4: Calculate auxiliary fuel required while vent(s) operate, scfm	11.83	FFmin
STEP 5: Calculate total gas flow out of incinerator while vent(s) operate, scfm	1011.83	
Step 6: Calculate maximum auxiliary fuel flow	13.54	FFmax

(when no emissions are vented), scfm

Step 7: Calculate maximum total gas flow out of incinerator, scfm 1013.54 scfm

## Utility requirements

Electricity, kwh/yr 50,208  $Kwh = (0.000117)(scfm)(29 \text{ in. H}_2\text{O})(CDh)/0.6$   
 - combined fan/motor efficiency of 60 percent  
 Natural gas  
 --scf/yr 6,828,452  $GASft3 = ((FFmax)(1-Ratio) + (FFmin)(Ratio))(60)(CDh)$   
 --Btu/yr 6,828,451,598  $GASbtu = (GASft3)(1,000 \text{ Btu/scf})$

## Chemical Engineering Magazine cost indexes

June 1995 plant index 382  
 Feb 1989 plant index 352.4  
 June 1995 equipment index 428.6  
 April 1988 plant index 340.1  
 342.5

## Unit costs

Elbows, \$/ea. 48.08  $Eone = (0.85)(1.65)(scfm)^{0.5}(382/352.4)$   
 SS round duct diam. of main, \$/ft 29.14  $Duct = (0.85)(scfm)^{0.5}(382/352.4)$   
 Automatic damper, \$/ea. 854.18  $ADone = (215 * scfm^{0.5} + 722)(382/352.4)$   
 Detonation arrestor, \$/ea. 5,000  $DAone$   
 Operator labor wage rate, \$/hr 15.64  $WRo$   
 Maintenance labor wage rate, \$/hr 17.21  $WRm$

## Capital Costs for Incinerator (June 1995 dollars), \$

## Purchased equipment costs

## Equipment

Recuperative incinerator 151,754  $RI = (21,342)(scfm)^{0.25}(428.6/340.1)$   
 - use 500 scfm when max scfm from step 7 is less than 500

## Instrumentation

15,175  $I = (RI)(0.1)$

## Sales tax

4,553  $S = (RI)(0.03)$

## Freight

7,588  $F = (RI)(0.05)$

## Total purchased equipment cost

179,070  $PECi = RI + I + S + F$

## Direct installation costs

53,721  $DI = (PECi)(0.3)$

## Indirect costs (installation)

55,512  $II = (PECi)(0.31)$

## Total capital investment

288,303  $TCIi = PECi + DI + II$

## Capital Costs for Manifolding (June 1995 dollars), \$

## Purchased equipment cost

## Ductwork

## Elbows

577  $Eall = (Eone)(Vents)(N)$

## Round duct

8,741  $RD = (Duct)(L)$

## Automatic damper

854  $AD = ADone$

## Detonation arrestors

30,000  $DA = (DAone)(Vents)$

## Total (w/ instr., sales tax, &amp; freight)

47,403  $PECd = (Eall + RD + AD + DA) * 1.18$

## Installation (assume equal to PEC)

47,403  $Im = (PECd)$

## Total capital investment

94,806  $TCIm = PECd + Im$

## Capital Costs for Monitoring (June 1995 dollars), \$

## Initial performance test

24,420 TEST

## Thermocouple and datalogger

3,000 TD

## Total capital investment

346,064 TCI

- If scfm from step 7 < 20,000;

then  $TCI = 1.25 \times PECi + TCI_m + TEST + TD$   
 - If scfm from step 7  $\geq 20,000$ ;  
 then  $TCI = TCI_i + TCI_m + TEST + TD$

## Annual costs, \$/yr

## Direct annual costs

## Operating labor

Control device

8,563  $OL_c = (0.5 \text{ hr}/8\text{-hr shift})(WR_o)(CD_h)$ 

Monitoring

8,563  $OL_m = (0.5 \text{ hr}/8\text{-hr shift})(WR_o)(CD_h)$ 

Supervisory labor

2,569  $SL = (0.15)(OL_c + OL_m)$ 

Maintenance labor

9,422  $ML = (0.5 \text{ hr}/8\text{-hr shift})(WR_m)(CD_h)$ 

Maintenance materials

9,422  $MM = ML$ 

Monitoring supplies

500  $MS$ 

Utilities

Natural gas

22,534  $NG = (GASf3)(\$3.3/1,000 \text{ scf})$ 

Electricity

2,962  $Elec = (Kwh)(\$0.059/kwh)$ 

## Indirect annual costs

Overhead

23,424  $O = (0.6)(OL_c + OL_m + SL + ML + MM + MS)$ 

Administrative charges

6,921  $A = (0.02)(TCI)$ 

Property tax

3,461  $PT = (0.01)(TCI)$ 

Insurance

3,461  $INS = (0.01)(TCI)$ 

Capital recovery

49,279  $CR = (CRF)(TCI)$ 

- CRF, 0.1424, based on 10-yrs and 7% interest

## Total annual cost, \$/yr

151,082  $TAC = OL_c + OL_m + SL + ML + MM + MS + NG + Elec + O + A + PT + INS + CR$

## CONDENSER COST ALGORITHM (MACT floor)

## Variables and equations

Model number:	1	
Required condenser control efficiency:	0.9	eff
<b>Waste Gas Parameters</b>		
Mass flux of HAP, lb/yr	30,200	
Flowrate, scfm	1,000	Qin
Flowrate, acfm	1,000	
Temperature, degrees C		
- degrees C	25	
- degrees F	77	Tin
Pressure, mm Hg	760	Ptot
HAP molecular weight	92	MWhap
VOC mole fraction	0.00075	yin
VOC concentration, ppmv	752	
Non condensable mole fraction	0.9992	
<b>Operating hours</b>		
Vent	2,800	Vh
Control device	8,760	CDh
Ratio of HAP venting time to control device operating time	0.3196	Ratio=Vh/CDh
<b>Condenser design calculations</b>		
HAP pollutant	Toluene	
Antoine equation constants		
A	6.955	A
B	1344.8	B
C	219.48	C
HAP partial pressure at outlet, mm Hg	0.057	$PP = (P_{tot})(y_{in})(1 - eff) / (1 - (y_{in})(eff))$
- assumes ideal gas		
HAP mole fraction at outlet	0.00008	$y_{out} = PP / P_{tot}$
Condensation temperature		
- degrees C	-55.43	$T_{degc} = ((B / (A - \log_{10} PP)) - C)$
- degrees F	-67.77	$T_{CON} = (T_{degc})(1.8) + 32$
Condenser exit flowrate, ft <sup>3</sup> /min	729.91	
HAP critical temperature		
Molar heat of condensation, Btu/lbmole		
- at 25 degrees C		
- at TCON	16,928	Hcon
Molar heat capacity of HAP, Btu/lbmole/deg F	24.84	Cphap
Molar heat capacity of air, Btu/lbmole/deg F	6.95	Cpair
<b>Average characteristics during venting events</b>		
HAP in inlet stream		
- lbmole/hr	0.1151	$Min = (Q_{in})(y_{in})(60 \text{ min/hr}) / (392 \text{ scf3/lbmole})$
- lb/hr	10.59	$LBin = (Min)(MWhap)$
HAP in outlet stream		
- lbmole/hr	0.011514	$Mout = (Min)(1 - eff)$
- lb/hr	1.059	$LBout = (Mout)(MWhap)$
Heat load, Btu/hr		
Enthalpy change of condensed HAP	2,127	$DELHcon = (Min - Mout)(Hcon + (Cphap)(T_{in} - T_{CON}))$
Enthalpy change of noncondensed HAP	41	$DELHuncon = (Mout)(Cphap)(T_{in} - T_{CON})$
Enthalpy change of noncondensable "air"	153,892	$DELHair = (((Q_{in})(60 \text{ min/hr}) / (392)) - (Min))(Cpair)(T_{in} - T_{CON})$
Total enthalpy change		
- Btu/hr	156,060	$LOADmax = DELHcon + DELHuncon + DELHair$
- tons	13.005	$Rmax = (LOADmax) / 12,000$
Heat load during non venting periods		
- Btu/hr (assumed to be 10% of max load)	15,606	$LOADmin = (LOADmax)(0.1)$
- tons	1.301	$Rmin = (LOADmin) / 12,000$
Total annual condenser heat load, Btu/yr	529,980,709	
Log mean temperature difference, deg F:	54.41	
Coolant flow rate, lb/hr	9,596	Qcool

## Manifolding design parameters

Diameter of collection main (ft):	0.800	$D=((4)(Q_{in})/2,000/\pi)^{0.5}$
- calculated assuming a velocity of 2,000 ft/min		
Length of duct, ft	300	L
Total number of vents	6	Vents
Number of elbows per vent	2	N

## Costing factors:

Operator labor wage rate, \$/hr	\$15.64	WRo
Maintenance labor wage rate, \$/hr	\$17.20	WRm
Operating labor, hr/8-hr operation	0.5	
Supervisory labor, % of operating labor	15	
Maintenance labor, hr/8-hr operation	0.5	
Monitoring maintenance labor, hr/8-hr operation	0.5	

## Utility requirements

Electricity, kwh/yr	424,605	$Kwh=((R_{max})(Ratio)+(R_{min})(1-Ratio))*((-0.06973)(TCON)+3.446)*(CDh/0.85)$
---------------------	---------	---

## Chemical Engineering Magazine Cost Indexes

June 1995 plant index	382	
Feb 1989 plant index	352.4	
August 1990 plant index	354.8	

## Unit costs (June 1995 dollars)

Detonation arrestor, \$/ea	5,000	DAone
Stainless round duct, \$/ft	29.14	$Duct=(0.85)(Q_{in})^{0.5}(382/352.4)$
Elbows, \$/ea	48.08	$Eone=(0.85)(1.65)(Q_{in})^{0.5}(382/352.4)$
Automatic damper, \$/ea	854.18	$ADone=(215*Q_{in}^{0.5}+722)(382/352.4)$
Refrigeration unit cost, \$	157,501	$RU=(\exp(9.73-0.012*TCON+0.584*\ln(R_{max}))(382/354.8)$
-multistage packaged unit		

## Capital Costs (June 1995 dollars),\$

Equipment costs, \$		
Packaged refrigeration system	196,876	$ECR=(1.25)(RU)$
- includes instrumentation		
Auxiliary equipment (manifolding) costs		
Automatic damper (assume 1 per manifold)	854	$AD=ADone$
Total round duct cost	8,741	$RD=(Duct)(L)$
Total elbow cost (2/vent)	577	$Eall=(Eone)(Vents)(N)$
Detonation arrestors (1/vent)	30,000	$DA=(DAone)(Vents)$
Total	40,172	$ECA=Eall+RD+AD+DA$
Purchased equipment cost		
Packaged refrigeration system	212,626	$PECr+(ECR)(1.08)$
Auxiliary equipment	47,403	$PECa=(ECA)(1.18)$
Installation cost		
Packaged refrigeration system	31,894	$Ir=(PECr)(0.15)$
Auxiliary equipment (assume equal to PEC)	47,403	$Ia=PECa$
Monitoring costs		
Initial Performance test for condenser	24,420	TEST
Thermocouple and datalogger	3,000	TD
TOTAL CAPITAL INVESTMENT	366,747	$TCI=PECr+PECa+Ir+Ia+TEST+TD$

## Annual Costs, \$/yr

Direct annual costs		
Operating labor:	8,563	$OL=(0.5 \text{ hr/8-hr shift})(WRo)(CDh)$
Monitoring labor:	8,563	$MONL=(0.5 \text{ hr/8-hr shift})(WRo)(CDh)$
Supervisor labor:	2,569	$SL=(0.15)(OL+MONL)$

Maintenance labor:	9,419	$ML = (0.5 \text{ hr}/8\text{-hr shift})(WR_m)(CD_h)$
Maintenance materials:	9,419	$MM = ML$
Monitoring maintenance materials (supplies):	500	MONM
Electricity:	25,052	$ELEC = (Kwh)(\$0.059/kwh)$
Indirect annual costs		
Overhead	23,420	$O = (0.6)(OL + SL + ML + MONL + MM + MONM)$
Property taxes, insurance, administrative charges:	14,670	$PTIA = (0.04)(TCI)$
Capital Recovery	40,269	$CR = (CRF)(TCI)$
- CRF, 0.1098, based on 15 yrs and 7% interest		
TOTAL ANNUAL COST, \$/yr	142,443	$TAC = OL + SL + ML + MM + MONL + MONM + ELEC + O + PTIA + CR$
Emission reduction, Mg/yr	12.34	
COST EFFECTIVENESS, \$/Mg	\$11,543	

## Attachment 2

### Example calculations

1. Equation used to calculate concentration associated with flow rate cutoff:

$$C = (E \times 385 \times 1,000,000) / (MW \times Q \times 60 \times H)$$

where,

C = HAP concentration, ppmv

E = HAP emissions, lb/yr

MW = HAP molecular weight, lb/lbmole

Q = Manifolded flow rate from all vents, scfm

H = Process operating hours, h/yr

385 = cubic feet per lbmole at standard conditions

60 = min/h

1,000,000 = conversion factor to ppmv

For model process 2, the equation yields the following result:

$$\begin{aligned} C &= (88,200 \text{ lb/yr})(385 \text{ scf/lbmole})(1,000,000) \\ &\quad (85 \text{ lb/lbmole})(285 \text{ scfm})(60 \text{ min/h})(2,800 \text{ h/yr}) \\ &= 8,340 \text{ ppmv} \end{aligned}$$

2. Calculation of average flow rate for process 2 at surveyed plant 3 (page 11 of attachment 3):

$$\text{weighted flow for PV001} = (175 \text{ scfm})(168 \text{ h}/8,136 \text{ h}) = 3.61 \text{ scfm}$$

$$\text{weighted flow for PV002} = (175 \text{ scfm})(8,136 \text{ h}/8,136 \text{ h}) = 175 \text{ scfm}$$

$$\text{average flow rate for process} = 179 \text{ scfm}$$

3. Calculation of average concentration for process 2 at surveyed plant 3 (using the same equation for sample calculation number 1):

$$\begin{aligned} C &= (112,271 \text{ lb/yr})(385 \text{ scf/lbmole})(1,000,000) \\ &\quad (166 \text{ lb/lbmole})(179 \text{ scfm})(60 \text{ min/h})(8,136 \text{ h/yr}) \\ &= 2,980 \text{ ppmv} \end{aligned}$$



### Attachment 3

Data used to estimate maximum and average flow rates and HAP concentrations for manifolded vents for processes at surveyed plants



PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
Plant 17 (61-63)												
EM-0.45	PV002	METHYLENE CHLORIDE	85	0.962	1548	743.04	8.74	85.00	2.97	C	0.00800	37,667
2	PV001	ACETONITRILE	41	4.52	1920	1536	37.46	7.58	7.68	U	0.01333	27,700
2	PV001	METHYL ISOBUTYL KETONE	100	4.52	1920	16512	165.12	81.51	82.6	U	0.14333	122,087
2	PV003	METHYL ISOBUTYL KETONE	100	2.19	1920	0.008	0.00	0.00	4E-06	U	0.00000	0
2	PV004	METHYL ISOBUTYL KETONE	100	218906	1920	8E-05	0.00	0.00	4E-07	U	0.00000	0
max flow w/o last one: typical:												
				6.71		18,048	202.58	89.1			0.1567	100,900
				same								
3	PV001	ACETONITRILE	41	12.92	2424	484	11.80	0.95	2.42	U	0.00333	2,419
3	PV001	METHYL ISOCYANATE	57	12.92	2424	2424	42.53	4.78	12.12	U	0.01667	8,713
3	PV002	ACETONITRILE	41	4.13	2424	242	5.90	0.48	1.21	U	0.00166	3,783
3	PV002	METHYL ISOBUTYL KETONE	100	4.13	2424	242	2.42	0.48	1.21	U	0.00166	1,551
3	PV003	ACETONITRILE	41	4.13	2424	1188	28.98	2.34	5.94	U	0.00817	18,572
3	PV003	HEXANE	86	4.13	2424	11150	129.65	21.98	55.8	U	0.07666	83,100
3	PV003	METHYL ISOBUTYL KETONE	100	4.13	2424	146	1.46	0.29	0.73	U	0.00100	936
3	PV004	HEXANE	86	93.01	50.5	22	0.26	0.04	22	U	0.00726	349
3	PV004	METHYL ISOBUTYL KETONE	100	93.01	50.5	50.5	0.51	0.10	50.5	U	0.01667	690
3	PV005	HEXANE	86	2.14	50.5	22	0.26	0.04	22	U	0.00726	15,189
3	PV005	METHYL ISOBUTYL KETONE	100	2.14	50.5	50.5	0.51	0.10	50.5	U	0.01667	29,984
3	PV006	HEXANE	86	2.14	2424	872.6	10.15	1.72	4.36	U	0.00600	12,551
3	PV007	ACETONITRILE	41	4.67	2424	582	14.20	1.15	2.91	U	0.00400	8,046
3	PV007	HEXANE	86	4.67	2424	2036.2	23.68	4.01	10.18	U	0.01400	13,421
3	PV008	ACETONITRILE	41	1.63	2424	1454.4	35.47	2.87	7.27	U	0.01000	57,609
3	PV008	HEXANE	86	1.63	2424	3878.4	45.10	7.65	19.39	U	0.02667	73,239
3	PV008	METHYL ISOBUTYL KETONE	100	1.63	2424	1939.2	19.39	3.82	9.7	U	0.01333	31,493
3	PV009	ACETONITRILE	41	2.25	2424	4032	98.34	7.95	4032	U	0.02772	115,699
3	PV009	HEXANE	86	2.25	2424	1677.3	19.50	3.31	167.3	U	0.01153	22,946
3	PV010	ACETONITRILE	41	2.14	2424	242.4	5.91	0.48	1.21	U	0.00167	7,313
3	PV010	HEXANE	86	2.14	2424	970	11.28	1.91	4.85	U	0.00667	13,952
average:												
				129.2		33705.5	507.3	66.4			0.2786	12,495
				36								37,301
4	PV001	METHANOL	32	0.13	8064	27.4	0.86	0.00	0.14	U	0.00006	5,241
4	PV002	METHANOL	32	444.57	8064	187080	5846.25	13.56	935.4	U	0.38666	10,464
4	PV003	METHANOL	32	0.43	8064	145.2	4.54	0.01	0.73	U	0.00030	8,397
4	PV004	METHANOL	32	91.9	168	9912	309.75	0.72	99.12	U	0.98333	128,735
4	PV005	METHANOL	32	91.9	168	9912	309.75	0.72	99.12	U	0.98333	128,735
4	PV006	METHANOL	32	4.06	8064	4838.4	151.20	0.35	24.19	U	0.01000	29,634
4	PV007	METHANOL	32	11.51	8064	5322.2	166.32	0.39	26.61	U	0.01100	11,498
4	PV008	METHANOL	32	1.1	8064	1112.83	34.78	0.08	1112.83	U	0.00230	25,156

[illegible]

PROCESS  
NO. VENT #

HAP

MW

SCFM

DURATION  
HR/YRUNCON.  
LB/YRLBMOLE/  
YRAVG/  
MWCONTL.  
LB/YR

TYPE

LB/MIN

PPMV

## Plant 1 (1-4)

1	PV001	TOLUENE	92	3082	5040	131227.8	1426.39	40.25	6561.4	U	0.43395	589
1	PV002	TOLUENE	92	18481	5040	32279.6	350.87	9.90	32279.6	U	0.10674	24
1	PV003	BENZYL CHLORIDE	126.5	925	5040	2448.1	19.35	0.75	2448.1	C	0.00810	27
1	PV003	TOLUENE	92	925	5040	128862.7	1400.68	39.52	128862.7	U	0.42613	1,928
1	PV004	TOLUENE	92	51966	5040	5798.3	63.03	1.78	5798.3	U	0.01917	2
			average:	74454		300,617	3,260	92	175,950		0.99	56
				same								
2	PV001	TOLUENE	92	3082	336	5419.9	58.91	40.25	271	U	0.26884	365
2	PV002	TOLUENE	92	18481	336	1333.2	14.49	9.90	1333.2	U	0.06613	15
2	PV003	BENZYL CHLORIDE	126.5	925	336	101.1	0.80	0.75	101.1	C	0.00501	17
2	PV003	TOLUENE	92	925	336	5322.2	57.85	39.52	5322.2	U	0.26400	1,194
2	PV004	TOLUENE	92	51966	336	239.5	2.60	1.78	239.5	U	0.01188	1
			average:	74454		12,416	135	92	7,267		0.62	35
				same								
3	PV001	TOLUENE	92	3082	720	18723.4	203.52	40.25	936.3	U	0.43341	588
3	PV002	TOLUENE	92	18481	720	4605.6	50.06	9.90	4605.6	U	0.10661	24
3	PV003	BENZYL CHLORIDE	126.5	925	720	349.3	2.76	0.75	349.3	C	0.00809	27
3	PV003	TOLUENE	92	925	720	18385.9	199.85	39.52	18385.9	U	0.42560	1,925
3	PV004	TOLUENE	92	51966	720	827.3	8.99	1.78	827.3	U	0.01915	2
			average:	74454		42,892	465	92	25,104		0.99	56
				same								
4	PV001	TOLUENE	92	3082	720	8869	96.40	40.25	443.4	U	0.20530	279
4	PV002	TOLUENE	92	18481	720	2181.6	23.71	9.90	2181.6	U	0.05050	11
4	PV003	BENZYL CHLORIDE	126.5	925	720	165.5	1.31	0.75	165.5	C	0.00383	13
4	PV003	TOLUENE	92	925	720	8709.1	94.66	39.52	8709.1	U	0.20160	912
4	PV004	TOLUENE	92	51966	720	391.9	4.26	1.78	391.9	U	0.00907	1
			average:	74454		20,317	220	92	11,892		0.47	26
				same								

## PROCESS

NO. VENT #

HAP

MW

SCFM

DURATION  
HR/YRUNCON.  
LB/YRLBMOL/  
YRAVG/  
MWCONTL.  
LB/YR

TYPE

LB/MIN

PPMV

## Plant 21 (67-73))

1	PV002	METHANOL	32	8	8400	10080	315.00	1.69	100.8	U	0.02000	30,078
1	PV003	METHANOL	32	0.604	8400	22.74	0.71	0.00	21.6	U	0.00005	899
1	PV004	METHANOL	32	125.5	8400	2988	93.38	0.50	119.52	U	0.00593	568
1	PV005	METHANOL	32	4.5	8400	224.64	7.02	0.04	224.64	U	0.00045	1,192
1	PV006	METHANOL	32	450	8400	99426	3107.06	16.63	99426	U	0.19727	5,274
1	PV007	METHANOL	32	135	8400	27448	857.75	4.59	27448	U	0.05446	4,854
1	PV008	METHANOL	32	3.34	8400	239.04	7.47	0.04	239.04	U	0.00047	1,708
1	PV009	METHANOL	32	0.19	8400	432	13.50	0.07	4.32	U	0.00086	54,276
1	PV010	METHANOL	32	0.67	8400	463.68	14.49	0.08	463.68	U	0.00092	16,521
1	PV011	METHANOL	32	3.4	8400	207.36	6.48	0.03	10.368	U	0.00041	1,456
1	PV012	METHANOL	32	4.7	8400	15.84	0.50	0.00	15.84	U	0.00003	80
1	PV013	METHANOL	32	129	8400	52.992	1.66	0.01	13.248	U	0.00011	10
1	PV013	TOLUENE	92	129	8400	8481.6	92.19	1.42	8481.6	U	0.01683	546
1	PV014	TOLUENE	92	2.07	8400	15.84	0.17	0.00	15.84	U	0.00003	64
1	PV015	METHANOL	32	388	8400	705.6	22.05	0.12	705.6	U	0.00140	43
1	PV016	TOLUENE	92	2543	8400	132480	1440.00	22.15	2649.6	U	0.26286	433
1	PV017	METHANOL	32	14.71	8400	15.84	0.50	0.00	15.84	U	0.00003	26
1	PV018	TOLUENE	92	5.2	8400	43.2	0.47	0.01	43.2	U	0.00009	69
			average:	3,818		283,342	5,980	47	139,999		0.56	1,197
				same								

2	PV001	TOLUENE	92	1015	4056	2101	22.84	3.08	42	U	0.00863	36
2	PV002	TOLUENE	92	8.1	4056	13026	141.59	19.09	260.5	U	0.05353	27,653
2	PV003	TOLUENE	92	13.2	3682.5	4454	48.41	6.53	4454	U	0.02016	6,391
2	PV004	TOLUENE	92	9.8	3682.5	2983	32.42	4.37	2983	U	0.01350	5,765
2	PV005	TOLUENE	92	0.6	3682.5	218.5	2.38	0.32	218.5	U	0.00099	6,897
2	PV006	TOLUENE	92	36.5	3682.5	39991	434.68	58.61	1159.7	U	0.18100	20,751
			average:	1,083		62,774	682	92	9,118		0.278	1,073
				1,078								1,001

3	PV001	TOLUENE	92	1015	570	420.75	4.57	3.02	8.41	U	0.01230	51
3	PV002	TOLUENE	92	8.1	570	2608.65	28.35	18.73	52.2	U	0.07628	39,407
3	PV003	TOLUENE	92	13.2	570	891.99	9.70	6.40	891.99	U	0.02608	8,269
3	PV004	TOLUENE	92	9.8	570	597.46	6.49	4.29	597.46	U	0.01747	7,460
3	PV005	TOLUENE	92	0.6	570	286.15	3.11	2.05	286.15	U	0.00837	58,357
3	PV006	TOLUENE	92	36.5	570	8008.76	87.05	57.50	232.25	U	0.23417	26,848
			average:	1,083		12,814	139	92	2,068		0.375	1,447
				same								

4	PV001	TOLUENE	92	1015	127	33	0.36	3.08	0.66	U	0.00433	18
4	PV002	TOLUENE	92	8.1	127	204.6	2.22	19.09	4.09	U	0.02685	13,872

## PROCESS

PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
4	PV003	TOLUENE	92	13.2	57.8	69.96	0.76	6.53	69.96	U	0.02017	6,395
4	PV004	TOLUENE	92	9.8	57.8	46.86	0.51	4.37	46.86	U	0.01351	5,770
4	PV005	TOLUENE	92	0.6	57.8	3.43	0.04	0.32	3.43	U	0.00099	6,898
4	PV006	TOLUENE	92	36.5	57.8	628.1	6.83	58.61	18.2	U	0.18111	20,765
average:												
				1,083		986	11	92	143		0.247	954
				1,050								455
5	PV001	TOLUENE	92	1015	144	60.5	0.66	3.08	1.21	U	0.00700	29
5	PV002	TOLUENE	92	8.1	144	375.1	4.08	19.09	7.5	U	0.04341	22,430
5	PV003	TOLUENE	92	13.2	106	128.26	1.39	6.53	128.26	U	0.02017	6,393
5	PV004	TOLUENE	92	9.8	106	85.91	0.93	4.37	85.91	U	0.01351	5,768
5	PV005	TOLUENE	92	0.6	106	6.29	0.07	0.32	6.29	U	0.00099	6,898
5	PV006	TOLUENE	92	36.5	106	1151.6	12.52	58.61	33.4	U	0.18107	20,760
average:												
				1,083		1,808	20	92	263		0.266	1,028
				1,067								821
6	PV001	TOLUENE	92	1015	188	63.25	0.69	3.08	1.26	U	0.00627	26
6	PV002	TOLUENE	92	8.1	188	392.15	4.26	19.09	7.84	U	0.03890	20,099
6	PV003	TOLUENE	92	13.2	110.9	134.09	1.46	6.53	134.09	U	0.02015	6,389
6	PV004	TOLUENE	92	9.8	110.9	89.81	0.98	4.37	89.81	U	0.01350	5,764
6	PV005	TOLUENE	92	0.6	110.9	6.58	0.07	0.32	6.58	U	0.00099	6,897
6	PV006	TOLUENE	92	36.5	110.9	1203.93	13.09	58.61	34.91	U	0.18093	20,744
average:												
				1,083		1,890	21	92	274		0.261	1,007
				1,063								861
7	PV001	TOLUENE	92	1015	188	71.5	0.78	3.08	1.43	U	0.00631	26
7	PV002	TOLUENE	92	8.1	188	443.3	4.82	19.09	8.87	U	0.03909	20,196
7	PV003	TOLUENE	92	13.2	125.3	151.58	1.65	6.53	151.58	U	0.02016	6,392
7	PV004	TOLUENE	92	9.8	125.3	101.53	1.10	4.37	101.53	U	0.01350	5,767
7	PV005	TOLUENE	92	0.6	125.3	7.44	0.08	0.32	7.44	U	0.00099	6,902
7	PV006	TOLUENE	92	36.5	125.3	1360.97	14.79	58.61	39.47	U	0.18103	20,755
average:												
				1,083		2,136	23	92	310		0.261	1,009
				1,063								973

PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
Plant 7 (17,18)												
1	PV001	1,3-BUTADIENE	54	20	760	72800	1348.15	54	1456	U	1.59649	569,120
		average:		same								
2	PV001	CARBON DISULFIDE	76	10000	850	85	1.12	0.23	85	U	0.00167	1
2	PV002	CARBON DISULFIDE	76	10000	4450	450	5.92	1.22	450	U	0.00169	1
2	PV006	CARBON DISULFIDE	76	900	5300	10800	142.11	29.28	10800	U	0.03396	191
2	PV006	CARBON TETRACHLORIDE	154	900	5300	220	1.43	0.60	220	C	0.00069	2
2	PV007	CARBON DISULFIDE	76	4000	850	240	3.16	0.65	240	U	0.00471	6
2	PV007	CARBON TETRACHLORIDE	154	4000	850	30	0.19	0.08	30	C	0.00059	0.4
2	PV008	CARBON DISULFIDE	76	350	5300	15000	197.37	40.67	15000	U	0.04717	683
2	PV009	CARBON DISULFIDE	76	4000	4450	1260	16.58	3.42	1260	U	0.00472	6
2	PV009	CARBON TETRACHLORIDE	154	4000	4450	150	0.97	0.41	150	C	0.00056	0
		average:		29,250		28,235	369	76.5			0.096	16
				15,250								29



page 8

PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
Plant 9 (25)												
2	PV001	CARBON TETRACHLORIDE	154	1.8	3334	33849	220	137	3.4	C	0.16671	231,543
2	PV001	HEXACHLOROETHANE	237	1.8	3334	6286	27	26	0.6	C	0.03096	27,940
2	PV002	CARBON TETRACHLORIDE	154	0.17	701	0.003	1.95E-05	0	0.003	C	0.00000	1
2	PV003	CARBON TETRACHLORIDE	154	NA	0	0	0	0	0	C	ERR	ERR
				1.97		40,135	246	163			0.19767	237,092
				1.84								253,843

PROCESS  
NO. VENT #

HAP

MW

SCFM

DURATION  
HR/YRUNCON.  
LB/YRLBMOL/  
YRAVG/  
MWCONTL.  
LB/YR

PPMV

TYPE

Plant 10 (27)

2	PV001	CARBON TETRACHLORIDE	154	1.6	7680	18161	117.9	41.4	9080	0.03941	61,581
2	PV001	TETRACHLOROETHYLENE	166	1.6	7680	2551	15.4	5.8	1275	0.00554	8,025
2	PV002	CARBON TETRACHLORIDE	154	7.2	7680	24583	159.6	56.1	24337	0.05335	18,524
2	PV002	TETRACHLOROETHYLENE	166	7.2	7680	16006	96.4	36.5	15847	0.03474	11,189
2	PV003	CARBON TETRACHLORIDE	154	131.8	7680	6833	44.4	15.6	75.9	0.01483	281
2	PV003	TETRACHLOROETHYLENE	166	131.8	7680	788	4.7	1.8	7.4	0.00171	30
		average:		140.6		68,922	438	157		0.14957	2,606
				same							

## PROCESS

NO. VENT # HAP

Plant 3 (6, 7, 11, 12)

		MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOL/ YR	AVG/ MW	CONTL. LB/YR	LB/MIN	PPMV
2 PV001	TETRACHLOROETHYLENE	166	175	168	2271	13.7	3.4	2271 C	0.22530	2,986
2 PV002	TETRACHLOROETHYLENE	166	175	8136	110000	662.7	162.6	11 C	0.22534	2,986
	average:		350		112,271	676	166		0.45063	2,986
			179							2,980
3 PV001	CARBON TETRACHLORIDE	154	80	5208	542	3.5	34.8	542 C	0.00173	54
3 PV001	CHLOROFORM	119	80	5208	313	2.6	20.1	313 C	0.00100	41
3 PV001	ETHYL CHLORIDE	64.5	80	5208	543	8.4	34.9	543 C	0.00174	130
3 PV001	TRICHLOROETHYLENE	131.5	80	5208	130	1.0	8.4	130 C	0.00042	15
	average:		80		1,528	16	98		0.00489	240
			same							
7 PV002	METHANOL	32	0.015	7200	520	16.3	18.7	0.5 U	0.00120	965,471
7 PV003	METHANOL	32	0.0088	7200	315	9.8	11.4	0.3 U	0.00073	996,908
7 PV006	METHANOL	32	0.0015	7200	53	1.7	1.9	0.05 U	0.00012	984,037
	average:		0.0253		888	27.75	32		0.002056	977,506
			same							
8 PV001	METHANOL	32	0.024	2400	280	8.8	5.2	28 U	0.00194	974,754
8 PV002	METHANOL	32	0.046	2400	550	17.2	10.2	55 U	0.00382	998,972
8 PV003	METHANOL	32	0.024	2400	280	8.8	5.2	28 U	0.00194	974,754
8 PV004	METHANOL	32	0.0012	2400	14	0.4	0.3	1 U	0.00010	974,754
8 PV005	METHANOL	32	0.027	2400	320	10.0	5.9	32 U	0.00222	990,226
8 PV006	METHANOL	32	0.023	2400	280	8.8	5.2	28 U	0.00194	1,017,135
	average:		0.1452		1724	53.875	32		0.011972	992,017
			same							



PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	LB/MIN	PPMV
Plant 20 (66)											
2	PV001	MALEIC ANHYDRIDE	98	1.51	840	5.76	0.1	0.002	5.76	0.00011	297
2	PV002	ACETONITRILE	41	12.44	840	413.58	10.1	0.121	413.58	0.00821	6,194
2	PV003	ACETONITRILE	41	36.89	840	140000	3414.6	40.879	560	2.77778	707,075
2	PV004	ACETONITRILE	41			40000			800		
average:				50.84		140,419	3,425	41		2.79	514,585
				same							

PROCESS  
NO. VENT #

HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOL/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
ETHYLENE DICHLORIDE	99	1400	2320	29	0.29	1.14	9	C	0.00021	1
FORMALDEHYDE	30	1400	2320	754	25.13	29.65	226	U	0.00542	50
average:		1400		783	25.4	30.8			0.00563	50
ETHYLENE DICHLORIDE	99	1400	1340	17	0.17	1.16	5	C	0.00021	1
FORMALDEHYDE	30	1400	1340	436	14.53	29.65	131	U	0.00542	50
average:		1400		453	14.7	30.8			0.00563	50
ETHYLENE DICHLORIDE	99	2000	7488	6300	63.64	70.3	228	C	0.01402	27
ETHYLENE DICHLORIDE	99	2900	7488	2570	25.96	28.7	2570	C	0.00572	8
average:		4900		8870	89.6	99.0			0.01974	16
ETHYL CHLORIDE	64.5	270	350	780	12.09	19.9	0.78	C	0.03611	798
METHYL CHLORIDE	50.5	270	350	290	5.74	7.4	0.29	C	0.01343	379
TOLUENE	92	270	350	3075	33.42	78.5	3.2	U	0.14236	2,206
average:		270		3365	39.2	85.9			0.19190	3,185
FORMALDEHYDE	30	1.7	4150	4.1	0.14	0.0	4.1	U	0.00002	124
METHANOL	32	1.7	4150	85	2.66	0.0	85	U	0.00034	2,416
TRIETHYLAMINE	101	1.7	4150	390	3.86	0.2	390	U	0.00157	3,512
FORMALDEHYDE	30	4.6	4150	14	0.47	0.0	14	U	0.00006	157
METHANOL	32	4.6	4150	33	1.03	0.0	33	U	0.00013	347
TRIETHYLAMINE	101	4.6	4150	43	0.43	0.0	43	U	0.00017	143
FORMALDEHYDE	30	2.9	4150	0.023	0.00	0.0	0.046	U	0.00000	0
FORMALDEHYDE	30	2.9	4150	0.023	0.00	0.0	0.023	U	0.00000	0
METHANOL	32	0.87	4150	3.9	0.12	0.0	3.9	U	0.00002	217
FORMALDEHYDE	30	4.6	4150	14	0.47	0.0	14	U	0.00006	157
METHANOL	32	4.6	4150	33	1.03	0.0	33	U	0.00013	347
TRIETHYLAMINE	101	4.6	4150	43	0.43	0.0	43	U	0.00017	143
ETHYLENE DICHLORIDE	99	190	4150	26	0.26	0.0	8	C	0.00010	2
FORMALDEHYDE	30	190	4150	70	2.33	0.0	21	U	0.00028	19
TOLUENE	92	190	4150	7	0.08	0.0	2.1	U	0.00003	1
FORMALDEHYDE	30	76	4150	33	1.10	0.0	33	U	0.00013	22
TRIETHYLAMINE	101	76	4150	295	2.92	0.1	295	U	0.00118	59
TOLUENE	92	1.7E-05	4150	5.6	0.06	0.0	5.6	U	0.00002	5,536,211
ETHYLENE DICHLORIDE	99	500	4150	0.9	0.01	0.0	0.26	C	0.00000	0

Plant 23 (89-94)

average:

PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION		UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL.		LB/MIN	PPMV
					HR/YR	LB/YR				LB/YR	TYPE		



PROCESS NO.	VENT #	HAP	MW	SCFM	DURATION HR/YR	UNCON. LB/YR	LBMOLE/ YR	AVG/ MW	CONTL. LB/YR	TYPE	LB/MIN	PPMV
Plant 8 (19)												
1	PV001	METHANOL	32	7730	7896	113999	3,562	14.1	2280	U	0.24063	375
1	PV002	XYLENES	106	1187	7896	238361	2,249	29.5	4767	U	0.50313	1,540
1	PV003	METHANOL	32	1922	7896	72545	2,267	9.0	1451	U	0.15313	959
1	PV005	METHANOL			8760	3695			3695	U		
1	PV005	TRICHLORO BENZENE			8760	95			95	C		
1	PV005	XYLENES			8760	16268			16268	U		
average:				10839		424905	8,078	52.6			0.89688	606
				same								

Shaded hours were changed to equal process operating hours



Date: June 30, 1997

Subject: Basis for Pollution Prevention Factors for the Production of Pesticide Active Ingredients NESHAP  
EPA Contract No. 68D60012; Task Order 0004  
ESD Project No. 93/59; MRI Project No. 4800-04

From: David Randall

To: Lalit Banker  
ESD/OCG (MD-13)  
U. S. Environmental Protection Agency  
Research Triangle Park, NC 27711

## I. Introduction

The purpose of this memorandum is to describe the basis for pollution prevention (P2) alternative standards to the MACT standards for process vents, storage tanks, equipment leaks, and wastewater systems for pesticide active ingredient manufacturing facilities.

## II. Background

Hazardous air pollutants that are emitted from a PAI process may be solvents, reactants above the stoichiometric amount needed in a reaction, byproducts generated in a reaction, or the product of a reaction. Solvent and reactant emissions are losses from the process that, together with losses of the same compounds in wastewater discharge or solid (or hazardous) waste disposal, can be related to consumption of purchased materials. Reducing solvent and reactant losses, as tracked by consumption records, forms the basis of pollution prevention alternative standards.

Losses to wastewater or waste disposal may not be equivalent to HAP emissions from the PAI process. However, reducing these losses would reduce other emissions. For example, HAP emissions from treatment technologies (e.g., incineration), and emissions from the generation of energy to operate the treatment technology, would be reduced. The plant producing the HAP compound would have reduced emissions due to reduced production. Emissions from transportation of the waste for disposal would also be reduced.

### III. Pollution Prevention Standard

Two P2 options were developed, and both options would be applied on a process basis.

#### A. Option 1

Under option 1, a facility would track HAP material usage and product production rates. The format of the standard would be the mass of HAP consumed per unit mass of product produced. This ratio is termed the "HAP factor." Compliance with the process vent, storage tank, equipment leak, and wastewater MACT standards for a given process would be demonstrated by showing the annual HAP factor is reduced by 85 percent from a baseline HAP factor. The 85 percent reduction was developed using the data in Table 1. The second column shows the nationwide uncontrolled HAP emissions from process vents, equipment leaks, and storage tanks in the PAI manufacturing industry; also shown is the nationwide HAP load in wastewater discharges from PAI processes. The third column shows the emissions and load after implementation of the MACT standards. The fourth column shows the overall reduction is 88 percent; for the P2 option, this value was rounded to down 85 percent (this may provide a small incentive to implement pollution prevention techniques). Note that this is a national average reduction; for individual facilities (or individual processes) it may result in either higher or lower reductions than would be achieved by the MACT standards, depending on the type of changes the plant implements and the level of reduction that would have been required under the MACT standards (i.e., some process vent emissions must be reduced 90 percent, and others must be reduced by 98 percent).

TABLE 1. HAP DISCHARGES FROM THE PAI MANUFACTURING INDUSTRY

Type of discharge	Uncontrolled discharges, Mg/yr	Discharges after MACT, Mg/yr	Reduction, percent
PV emissions	16,500	600	96
EL emissions	3,700	390	89
ST emissions	220	17	92
WW load	6,800	2,310	66
Totals	27,200	3,320	88

The baseline year was selected to be 1987 because this was the first year for the SARA/TRI reporting requirements. If the process was not operating in 1987, the baseline year would be the first calendar year of operation after 1987. Similarly, if either consumption or production data are not available for 1987, the baseline year would be the first calendar year for which data are available.

To demonstrate ongoing compliance with the P2 standard, the facility would have to calculate the annual HAP factor at regular intervals. The frequency of the calculation is an

important issue. Continuous compliance would require essentially instantaneous calculations during process operation, which would be impossible. Daily measurements of consumption and production would be feasible (most likely using tank level measurements), but the resulting annual HAP factors for batch processes that last more than a day could fluctuate depending on the stage of the process at the end of the day and the number of days of operation in the past 12 months. Calculations over a longer term would damp out the fluctuation, but if the term is too long, the calculation would not serve the purpose of demonstrating compliance on a continuous basis. Calculations every 10 batches for batch processes and monthly for continuous processes seem like a reasonable compromise. Presumably, each exceedance would be considered a violation of the standard for however many days had elapsed since the last calculation (i.e., 30 violations for a continuous process, and up to 10 for a batch process--less than 10 if multiple batches are conducted per day).

One potential way to reduce the HAP factor would be to replace the HAP with a non-HAP VOC. However, this substitution would not be a true P2 measure. Therefore, the facility should also be required to demonstrate that VOC consumption per unit of product remains the same or is reduced. Therefore, a baseline VOC factor would need to be developed, and an annual VOC factor would be calculated every time the annual HAP factor is calculated.

The P2 standard could not be used for a HAP that is generated in the process because there is no usage quantity to track for such a HAP. In addition, compliance with the P2 standard would not be available for HAP emissions from product dryers because the HAP emissions are the product, not a material that is consumed. Emissions of these HAP's would have to be reduced in accordance with the MACT standards.

A storage tank or wastewater system that serves multiple processes would still have to meet the MACT standards for any process(es) not subject to the P2 alternative.

#### B. Option 2

A second option was developed that would allow a facility to take advantage of both pollution prevention techniques and add-on controls. Under this option, the facility would be required to achieve (1) at least a 50 percent reduction in the annual HAP factor relative to the baseline HAP factor, (2) emissions reductions that, when divided by the mass annual production, yields a value equivalent to at least a 35 percent reduction in the annual HAP factor, and (3) no increase in the VOC annual factor. Thus, the overall reduction would be equivalent to the 85 percent reduction under option 1. Note that no additional credit would be given for exceeding either the 50 or 35 percent requirements.

The calculation frequency of the HAP and VOC annual factors, and the exclusion of generated HAP, would be the same as under option 1. Demonstrating compliance with the 35 percent requirement for add on controls would be achieved using the same strategies as in the MACT standards. The reduction in emissions must be accomplished in such a way that the HAP is destroyed or otherwise prevented from being returned to the process; otherwise the emission reduction would also be counted as a reduction in consumption in the annual HAP factor.



Date: June 30, 1997

Subject: Basis for Applicability Cutoff Equation for Process Vents Under Regulatory  
Alternative No. 1--Pesticide Active Ingredient Production NESHAP  
EPA Contract No. 68D60012; Task Order No. 0004  
ESD Project No. 93/59; MRI Project No. 4800-04

From: David Randall

To: Lalit Banker  
ESD/OCG (MD-13)  
U. S. Environmental Protection Agency  
Research Triangle Park, NC 27711

## I. Introduction

A regulatory alternative more stringent than the MACT floor was developed that would require 98 percent control of organic HAP emissions from certain large process vent emission streams. This memorandum describes the procedure used to develop an equation to determine which process vent emission streams would be subject to the 98 percent control requirement. The resulting equation is also presented, and an estimate of the number of processes at the surveyed and modelled plants that would meet the requirement for 98 percent control is developed.

## II. Development of the Applicability Cutoff Equation

The methodology used to develop the equation is the same as that described in the Alternative Control Techniques Document for Batch Processes.<sup>1</sup> This methodology also was used to develop an equation for the Pharmaceuticals NESHAP.<sup>2</sup> Because the equation for a given pollutant should be the same regardless of the type of process causing the emission, the equation developed for the Pharmaceuticals NESHAP is also applicable to the PAI NESHAP. The remainder of this section summarizes the methodology used to develop the equation.

Variables that affect control costs are the type of control device, the type of pollutant, the pollutant concentration, the vent stream flow rate, and the operating hours. The concentration, flow rate, and operating hours define the annual mass emissions rate; this analysis uses the mass emissions rate as a variable instead of the the operating hours. The first step in the methodology was to select a representative pollutant for analysis. Methanol was selected as representative because it is a common pollutant from pharmaceutical processes (it is also emitted from many PAI processes), and it has a moderate volatility. The second step was to develop a

series of four graphs showing the relationship between cost effectiveness and flow rate for different mass emission rates, concentrations, and control devices. Each graph (shown in reference 1) was developed at a different annual mass emission rate (75,000, 100,000, 125,000, and 150,000 lb/yr). On each graph, separate curves were developed, each representing 98 percent control with either a condenser or an incinerator. Condensers tend to be less costly for concentrated streams, and incinerators tend to be the least costly for dilute streams. Therefore, a curve at saturated conditions (164,000 ppm) was developed for a condenser, a curve at a dilute concentration (1,000 ppm) was developed for an incinerator, and curves were developed for both an incinerator and a condenser at an intermediate concentration (10,000 ppm), because either device might be least costly. Taken together, the four curves represent the least costly means of control over a range of operating conditions. The third step was to define a target cost effectiveness cutoff; \$3,500/Mg was judged to be acceptable based on decisions for previously promulgated Part 63 rules for sources with organic HAP emissions. Therefore, the midpoint of the range of flowrates at \$3,500/Mg on each of the four graphs was identified and used in a plot of flow rate versus annual emission rate. The final step was to develop the equation of a line through these four points using linear regression. The resulting equation is as follows:

$$\text{Flow, scfm} = (0.02 * \text{Mass emissions, lb/yr}) - 1,000$$

To use this equation, the annual emissions from a process vent are inserted and a flow rate is calculated. If the calculated flow rate is higher than the actual flow rate, the vent stream would be subject to the 98 percent control requirement because control would cost less than \$3,500/Mg. Conversely, if the calculated flow rate is lower than the actual flow rate, the cost to control the vent stream would exceed \$3,500/Mg, and the vent stream would not be subject to the 98 percent control requirement. Further examination of the equation shows the calculated flow will be lower than the actual flow for any vent stream with a mass emission load less than 50,000 lb/yr.

## II. Estimated Number of Streams Subject to 98 Percent Control

The number of processes at the surveyed plants that meet the criteria for 98 percent control was estimated based on process and control data presented in Table 1; these data were extracted from two previous project memoranda.<sup>3,4</sup> The first step was to eliminate all processes with total organic HAP emissions less than 22.7 Mg/yr (50,000 lb/yr). The second step was to eliminate all of the remaining processes that are controlled to 90 percent or better (because the control of these streams would not need to be increased). This left five batch processes (15, 67, 68, 93, and 94) and two continuous processes (1 and 27) to check using the applicability cutoff equation. Flow rate data were available for all seven processes. Because some of these data were for manifolded streams (rather than for individual vents from unit operations), a simplifying assumption was to use the average aggregated process flow rates that were developed for a previous modelling analysis.<sup>4</sup> Three of the seven processes (15, 27, and 67) meet the criteria for 98 percent control. (Note that if the reported data for manifolded and individual vents were used, only one additional process would meet the criteria for 98 percent control).

TABLE 1. PROCESS VENTS FOR SURVEYED PROCESSES THAT MEET APPLICABILITY CUTOFF FOR 98 PERCENT CONTROL UNDER REGULATORY ALTERNATIVE NO. 1

Plant no.	Process no.	Process operating hr/yr	Uncontrolled emissions, Mg/yr			Controlled emissions, Mg/yr	Control eff., %	Avg. Flow, scfm	RA 1 Applic. cutoff eq. (a)		
			Chlorinated organics	Unchlorinated	Total				load > cutoff (y/n)	Control < 90 percent (y/n)	flow > actual flow (y, n, N/A) (b)
Batch processes											
15	57	3,960	0	0.276	0.276	0.276	0.0		n	yes	N/A
11	36	7,776	0	0.399	0.399	0.008	98.0		n	n	N/A
21	70	127	0	0.447	0.447	0.065	85.5	1,050	n	yes	N/A
15	58	5,220	0	0.679	0.679	0.679	0.0		n	yes	N/A
3	12	4,176	0	0.782	0.782	0.078	90.0	0.145	n	n	N/A
21	71	148	0	0.820	0.820	0.119	85.5	1,030	n	yes	N/A
21	72	169	0	0.857	0.857	0.125	85.5	1,010	n	yes	N/A
21	73	189	0	0.969	0.969	0.141	85.5	1,010	n	yes	N/A
14	46	288	0	1.00	0.996	0.020	98.0		n	n	N/A
22	81	300	0	1.38	1.38	0.028	98.0		n	n	N/A
8	22	2,208	0	1.41	1.41	0.141	90.0		n	n	N/A
15	54	5,784	0	1.59	1.59	1.587	0.0		n	yes	N/A
14	43	792	0	1.74	1.74	0.034	98.0		n	n	N/A
14	44	696	0	1.76	1.76	0.035	98.0		n	n	N/A
14	47	576	0	2.28	2.28	0.046	98.0		n	n	N/A
14	45	840	0	3.19	3.19	0.064	98.0		n	n	N/A
22	77	1,184	0	4.54	4.54	0.091	98.0		n	n	N/A
22	76	1,776	0	4.54	4.54	0.091	98.0		n	n	N/A
21	69	570	0	5.81	5.81	0.938	83.9	1,080	n	yes	N/A
6	16	4,404	0	16.5	16.5	1.65	90.0	9.5	n	n	N/A
22	78	1,036	0	23.8	23.8	0.475	98.0		yes	n	N/A
12	38	1,170	0	24.3	24.3	0.504	97.9	1,993	yes	n	N/A
21	68	4,056	0	28.5	28.5	4.14	85.5	1,080	yes	yes	no
7	17	6,072	0	33.0	33.0	0.660	98.0	20	yes	n	N/A
19	64	6,318	0	34.3	34.3	0.171	99.5		yes	n	N/A
22	85	1,542	0	66.7	66.7	1.33	98.0		yes	n	N/A
20	66	840	0	81.8	81.8	0.807	99.0	50.8	yes	n	N/A
22	84	2,496	0	96.3	96.3	1.93	98.0		yes	n	N/A
23	90	1,340	0.00771	0.198	0.205	0.062	70.0	1,400	n	yes	N/A
23	89	2,320	0.0132	0.342	0.355	0.107	70.0	1,400	n	yes	N/A
17	60	1,548	0.337	0	0.337	0.007	98.0	0.962	n	n	N/A
23	92	360	0.486	1.39	1.88	0.038	98.0	270	n	n	N/A
3	7	8,160	0.693	0	0.693	0.693	0.0	80	n	yes	N/A
22	83	1,946	22.7	6.27	29.0	0.579	98.0		yes	n	N/A
23	93	4,150	40.1	18.6	58.7	13.5	76.9	6,884	yes	yes	no
5	15	6,039	42.8	9.05	51.9	51.9	0.0	23.7	yes	yes	yes
22	82	8,760	45.4	12.2	57.6	1.15	98.0		yes	n	N/A
8	20	2,208	0.0454	15.2	15.3	1.53	90.0		n	n	N/A
3	11	8,160	0	0.403	0.403	0.000	99.9	0.0253	n	n	N/A
12	37	1,368	0	4.59	4.59	0.092	98.0	76	n	n	N/A
21	67	8,400	0	129	129	63.5	50.6	3,818	yes	yes	yes
12	40	1,568	32.8	15.4	48.2	3.11	93.5	6.3	yes	n	N/A
23	94	4,370	26.5	38.5	65.0	15.2	76.7	6,884	yes	yes	no
22	79	432	8.30	0	8.30	0.166	98.0		n	n	N/A
22	75	4,500	53.1	0	53.1	1.06	98.0		yes	n	N/A
9	24	5,568	0	0	0.000	0.000			n	yes	N/A

(a) The applicability equation is discussed in section II of this memorandum.

(b) "N/A" means the flow was not calculated because the load was below the applicability threshold of 22.68 Mg/yr (50,000 lb/yr), or the control efficiency is greater than 90 percent. "No" means the calculated flow rate is lower than the actual flow rate, and "yes" means the actual flow rate is lower than the calculated flow rate.

TABLE 1. PROCESS VENTS FOR SURVEYED PROCESSES THAT MEET APPLICABILITY CUTOFF FOR 98 PERCENT CONTROL UNDER REGULATORY ALTERNATIVE NO. 1 (continued)

Plant no.	Process no.	Process operating hr/yr	Uncontrolled emissions, Mg/yr			Controlled emissions, Mg/yr	Control eff., %	Avg. Flow, scfm	RA 1 Applic. cutoff eq.(a)		
			Chlorinated organics	Unchlorinated	Total				Control < 90 percent (y/n)	flow > actual flow (y, n, N/A) (b)	
Continuous processes											
5	14	7,464	0	0.916	0.916	0.0272	97.0	125.0	n	n	N/A
22	80	456	0	1.81	1.81	0.0363	98.0		n	n	N/A
17	61	1,920	0	8.19	8.19	0.164	98.0	6.7	n	n	N/A
17	62	2,424	0	15.3	15.3	2.91	81.0	36.0	n	yes	N/A
17	63	8,064	0	200	200	5.22	97.4	486	yes	n	N/A
1	2	336	0.0459	5.59	5.63	3.30	41.4	74,500	n	yes	N/A
1	4	720	0.0751	9.14	9.22	5.40	41.4	74,500	n	yes	N/A
1	3	720	0.158	19.3	19.5	11.4	41.4	74,500	n	yes	N/A
7	18	5,300	0.181	12.6	12.8	12.8	0.0	15,250	n	yes	N/A
1	1	5,040	1.11	135	136	79.8	41.5	74,500	yes	yes	no
10	27	7,680	31.3	0	31.3	23.0	26.5	141	yes	yes	yes
3	6	8,136	50.9	0	50.9	2.03	96.0	179	yes	n	N/A
11	33	7,176	60.3	4.4	64.7	5.25	91.9		yes	n	N/A
8	23	7,896	0	0	0.0	0.0			n	yes	N/A
8	19	7,896	0.0431	202	202	12.9	93.6	10,800	yes	n	N/A
23	91	7,488	4.02	0	4.02	1.38	65.7	4,900	n	yes	N/A
12	39	7,000	199	0	199	5.93	97.0	122	yes	n	N/A
9	25	3,384	18.2	0	18.2	0.364	98.0	1.8	n	n	N/A
22	74	5,184	347	0	347	6.94	98.0		yes	n	N/A

(a) The applicability equation is discussed in section II of this memorandum.

(b) "N/A" means the flow was not calculated because the load was below the applicability threshold of 22.68 Mg/yr (50,000 lb/yr), or the control efficiency is greater than 90 percent. "No" means the calculated flow rate is lower than the actual flow rate, and "yes" means the actual flow rate is lower than the calculated flow rate.

The approach to estimate how many of the 93 projected processes at the 58 modelled plants that would meet the criteria for 98 percent control was estimated by extrapolating from the data for surveyed processes; the data and results are shown in Table 2. The surveyed processes are organized into four groups in Table 2, each group containing processes that were used to establish the characteristics of one of the four model processes. Of the 33 surveyed processes used to characterize model 1, 8 have annual mass emissions above 50,000 lb/yr. Flow rates are available for four of these eight processes, and two of the four would meet the criteria for 98 percent control. Therefore, it was assumed that 12 percent of the 48 projected processes (i.e., 6 processes) represented by model 1 would meet the criteria for 98 percent control ( $8/33 * 2/4 * 48 = 6$ ). Similar procedures were used to estimate the number of projected processes represented by models 2, 3, and 4 that would meet the criteria for 98 percent control. The data and results are shown in Table 3.

The final step in the analysis for the projected processes was to estimate whether the vent stream is concentrated or dilute. These estimates were based on the ratio of concentrated to dilute surveyed processes that meet the criteria for 98 percent control. For example, surveyed processes 15, 40, and 67 are the only processes used to characterize model number 2 that also meet the criteria for 98 percent control. Two of these processes have concentrated vent streams, and one has a dilute vent stream. Therefore, approximately two-thirds, or five, of the seven projected processes represented by model number 2 were assumed to have concentrated vent streams, and one-third, or two, of the seven were assumed to have dilute vent streams. Similar procedures were used to estimate the dilute and concentrated vent streams for the other projected processes, and the results are shown in Table 4.

TABLE 2. PROCESS VENTS FOR MODELLED PROCESSES THAT MEET APPLICABILITY CUTOFF FOR 98 PERCENT CONTROL UNDER REGULATORY ALTERNATIVE NO. 1

Plant no.	Process no.	Process operating hr/yr	Uncontrolled emissions, Mg/yr				Avg. Flow, scfm	RA 1 Applic. cutoff eq. (b)	
			Chlorinated organics	Unchlorinated	HCl/Cl2	Total		load > cutoff (y/n)	flow > actual flow (y, n, N/A) (c)
Batch processes									
15	57	3,960	0	0.276	0	0.276		n	N/A
11	36	7,776	0	0.399	0	0.399		n	N/A
21	70	127	0	0.447	0	0.447	1,050	n	N/A
15	58	5,220	0	0.679	0	0.679		n	N/A
3	12	4,176	0	0.782	0	0.782	0.145	n	N/A
21	71	148	0	0.820	0	0.820	1,030	n	N/A
21	72	169	0	0.857	0	0.857	1,010	n	N/A
21	73	189	0	0.969	0	0.969	1,010	n	N/A
14	46	288	0	1.00	0	1.00		n	N/A
22	81	300	0	1.38	0	1.38		n	N/A
8	22	2,208	0	1.41	(a)	1.41		n	N/A
15	54	5,784	0	1.59	0.157	1.74		n	N/A
14	43	792	0	1.74	0	1.74		n	N/A
14	44	696	0	1.76	0	1.76		n	N/A
14	47	576	0	2.28	0	2.28		n	N/A
14	45	840	0	3.19	0	3.19		n	N/A
22	77	1,184	0	4.54	0	4.54		n	N/A
22	76	1,776	0	4.54	0	4.54		n	N/A
21	69	570	0	5.81	0	5.81	1,080	n	N/A
6	16	4,404	0	16.5	0	16.5	9.5	n	N/A
22	78	1,036	0	23.8	0	23.8		yes	unknown
12	38	1,170	0	24.3	0.00014	32.0	1,993	yes	no
21	68	4,056	0	28.5	0	28.5	1,080	yes	no
7	17	6,072	0	33.0	0	33.0	20	yes	yes
19	64	6,318	0	34.3	0	34.3		yes	unknown
22	85	1,542	0	66.7	0	66.7		yes	unknown
20	66	840	0	81.8	0	81.8	50.8	yes	yes
22	84	2,496	0	96.3	0.101	96.4		yes	unknown
23	90	1,340	0.00771	0.198	0.410	0.616	1,400	n	N/A
23	89	2,320	0.0132	0.342	0.710	1.07	1,400	n	N/A
17	60	1,548	0.337	0	0	0.337	0.962	n	N/A
23	92	360	0.486	1.39	0.00064	1.88	270	n	N/A
3	7	8,160	0.693	0	0	0.693	80	n	N/A
22	83	1,946	22.7	6.27	0	28.9		yes	unknown
23	93	4,150	40.1	18.6	0.557	59.2	6,884	yes	no
5	15	6,039	42.8	9.05	0	51.9	23.7	yes	yes
22	82	8,760	45.4	12.2	0	57.5		yes	unknown
8	20	2,208	0.0454	15.2	6.80	22.1		n	N/A
3	11	8,160	0	0.403	9.00	9.41	0.0253	n	N/A
12	37	1,368	0	4.59	11.0	15.6	76	n	N/A
21	67	8,400	0	129	12.0	141	3,818	yes	yes
12	40	1,568	32.8	15.4	26.7	74.9	6.3	yes	yes
23	94	4,370	26.5	38.5	33.1	98.1	6,884	yes	no
22	79	432	8.30	0	54.4	62.8		n	N/A
22	75	4,500	53.1	0	349	402		yes	unknown
9	24	5,568	0	0	356	356		n	N/A

(a) No data provided.

(b) The applicability equation is discussed in section II of this memorandum.

(c) "N/A" means the flow was not calculated because the load was below the applicability threshold of 22.68 Mg/yr (50,000 lb/yr).

"Unknown" means the actual flow rate was not reported.

"No" means the calculated flow rate is lower than the actual flow rate, and "yes" means the actual flow rate is lower than the calculated flow rate.

TABLE 2. PROCESS VENTS FOR MODELLED PROCESSES THAT MEET APPLICABILITY CUTOFF FOR 98 PERCENT CONTROL UNDER REGULATORY ALTERNATIVE NO. 1 (continued)

Plant no.	Process no.	Process operating hr/yr	Uncontrolled emissions, Mg/yr				Avg. Flow, scfm	RA 1 Applic. cutoff eq.(b)	
			Chlorinated organics	Unchlorinated	HCl/Cl2	Total		load > cutoff (y/n)	flow > actual flow (y, n, N/A) (c)
Continuous processes									
5	14	7,464	0	0.916	0	0.916	125.0	n	N/A
22	80	456	0	1.81	0	1.81		n	N/A
17	61	1,920	0	8.19	0	8.19	6.7	n	N/A
17	62	2,424	0	15.3	0	15.3	36.0	n	N/A
17	63	8,064	0	200	0	200	486	yes	yes
1	2	336	0.0459	5.59	0.0262	5.66	74,500	n	N/A
1	4	720	0.0751	9.14	0.0428	9.26	74,500	n	N/A
1	3	720	0.158	19.3	0.0904	19.5	74,500	n	N/A
7	18	5,300	0.181	12.6	0	12.8	15,250	n	N/A
1	1	5,040	1.11	135	0.633	137	74,500	yes	no
10	27	7,680	31.3	0	0	32.7	141	yes	yes
3	6	8,136	50.9	0	0	50.9	179	yes	yes
11	33	7,176	60.3	4.4	0.761	65.5		yes	unknown
8	23	7,896	0	0	14.5	14.5		n	N/A
8	19	7,896	0.0431	202	13.2	215	10,800	yes	no
23	91	7,488	4.02	0	117	121	4,900	n	N/A
12	39	7,000	199	0	67.2	266	122	yes	yes
9	25	3,384	18.2	0	174	192	1.8	n	N/A
22	74	5,184	347	0	2,360	2,707		yes	unknown

(a) No data provided.

(b) The applicability equation is discussed in section II of this memorandum.

(c) "N/A" means the flow was not calculated because the load was below the applicability threshold of 22.68 Mg/yr (50,000 lb/yr).

"Unknown" means the actual flow rate was not reported.

"No" means the calculated flow rate is lower than the actual flow rate, and "yes" means the actual flow rate is lower than the calculated flow rate.

**TABLE 3. PROJECTED PROCESSES THAT WOULD MEET CRITERIA FOR 98 PERCENT CONTROL**

Model process	Population of model processes nationwide <sup>5</sup>	Surveyed processes used to characterize the model processes			Number that meet criteria for 98 percent control	Estimated number of projected processes that meet criteria for 98 percent control
		Total number <sup>5</sup>	Organic HAP emissions >50,000 lb/yr <sup>5</sup>	Number with flow data <sup>6</sup>		
1	48	33	8	4	2 <sup>a</sup>	6
2	19	13	8	5	3 <sup>b</sup>	7
3	14	10	2	2	1 <sup>c</sup>	1
4	12	9	6	4	3 <sup>d</sup>	6

<sup>a</sup>processes 17 and 66

<sup>b</sup>processes 15, 40, and 67

<sup>c</sup>process 63

<sup>d</sup>processes 6, 27, and 39

**TABLE 4. DILUTE AND CONCENTRATED STREAMS FOR PROCESSES THAT MEET CRITERIA FOR 98 PERCENT CONTROL**

Model process	Surveyed processes that meet criteria for 98 percent control <sup>a</sup>			Estimated number of projected processes that meet criteria for 98 percent control		
	Total number	Concentrated processes	Dilute processes	Concentrated processes	Dilute processes	Total number
1	2	17 and 66	none	6	0	6
2	3	15 and 40	67	5	2	7
3	1	63	none	1	0	1
4	3	39	6 and 27	2	4	6

<sup>a</sup>See Table 2.

### III. References

1. Control of VOC Emissions From Batch Processes--Alternative Control Techniques Document. EPA 453/R-94-020. February 1994.
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5. D. Randall, MRI, to L. Banker, EPA:ESD. April 30, 1997. Model Plants for the Pesticide Active Ingredient Manufacturing Industry.
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